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STURGEON SPAWNING IN THE SACRAMENTO RIVER IN 1973, AS DETERMINED BY DISTRIBUTION OF LARVAE[1]

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To determine the time and location of sturgeon spawning in the Sacramento River, California, sampling was conducted three times per week from March 5 to June 17, 1973 at six locations from the mouth of the Feather River to above Red Bluff. A total of 246 larvae and nine eggs was collected at the mouth of the Feather River, at river km 180 (river mile 112), and at Colusa. Spawning probably occurred from the vicinity of Knights Landing to just above Colusa. Spawning occurred from mid-February to late May, although the majority (93%) was in March and April. Water temperatures during those 2 months ranged from 7.8 to 17.8 C (46 to 64 F). Spawning peaked from April 8 to 17 at a temperature of approximately 14.4 C (58 F). Mean size of larvae increased each month, probably because the growth rate increased with water temperature. Both white sturgeon (*Acipenser transmontanus*) and green sturgeon (*A. medirostris*) occur in the Sacramento-San Joaquin Estuary. While the larvae could not be identified, most were probably white sturgeon since that species dominates the Sacramento River sturgeon fishery.

INTRODUCTION

Information about the spawning of sturgeon in the Sacramento-San Joaquin Estuary, California, is very limited. Until 1965, nothing was known. That year two sturgeon larvae were collected in the Sacramento River near Rio Vista during a striped bass spawning survey. During surveys in 1966, 1967, and 1968, sturgeon larvae were captured in the Sacramento River as far upstream as Verona and in the Sacramento-San Joaquin Delta (Stevens and Miller 1970). During spring 1972 a few larvae were taken as far upstream as Colusa (Jerry Turner, Calif. Dept. Fish and Game, unpublished).

My study was designed to determine the time and location of sturgeon spawning in the Sacramento River by collecting larvae as they moved downstream after hatching.

MATERIALS AND METHODS

Six sampling locations were chosen at 51–64 km (32–40 mile) intervals on the Sacramento River from the mouth of the Feather River to above Red Bluff (Figure 1). Sampling sites were above the mouth of the Feather River at river km (rkm) 129 (river mile [rm] 80); rkm 180 (rm 112); Colusa, rkm 233 (rm 145); Ord Bend, rkm 297 (rm 185); Woodson Bridge, rkm 351 (rm 218); and Bend Bridge, rkm 412 (rm 256). It was necessary to terminate sampling at Ord Bend and sample at Pine Creek, rkm 317 (rm 197), approximately half-way through the survey (Figure 1).

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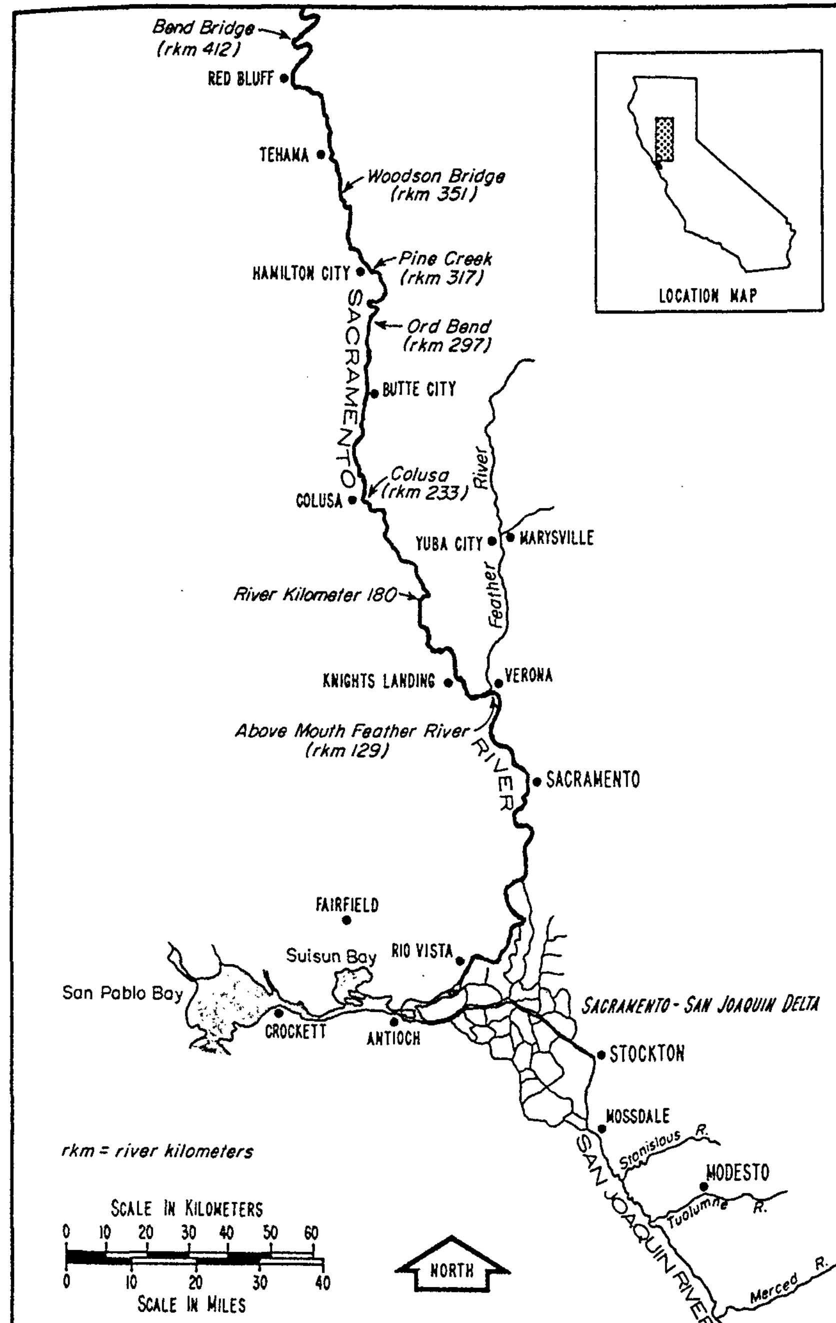

FIGURE 1. Sturgeon larvae sampling sites on the Sacramento River in 1973.

Collections were made three times per week (usually on Monday, Wednesday, and Friday) at each site from March 5 to June 17, 1973. Sampling was occasionally omitted because of equipment failure, dangerous river flows, and silted launching ramps.

Two boats were used for sampling, one for the lower two stations and the other for the upper four.

Larvae were collected with a cone-shaped net constructed of 7.9 mesh/cm (20 mesh/inch) marquisette nylon netting, 3.4 m (11.2 ft) long, and 0.8 m (30 inches) wide at the mouth. This net was attached to an inverted U-shaped frame (1.3 cm [0.5 inch] ID galvanized iron pipe) with a circumference of approximately 2.3 m (7.5 ft). A polyethylene collecting jar was attached to the cod end. A 6 cm by 8 cm (2.4 by 3.1 inch) hole on one side of the jar was screened with 11.8 mesh/cm (30 mesh/inch) stainless steel bolting cloth.

The net was fished from an anchored boat. Two lead weights on each end of the frame held the net near the river bottom. The bottom of the mouth was approximately 10 cm (4 inches) above the substrate. Previous studies demonstrated that sturgeon larvae in the Sacramento River concentrate near the bottom (Stevens and Miller 1970).

Net sets varied from 5 min to 1 h, depending on the amount of debris collected. When sampling time was short, sets were repeated for a cumulative total of at least 30 min. These periods exclude raising and lowering the net.

Surface water temperatures were measured at each station while the net was fishing.

Samples with little debris were sorted in the field and the larvae were preserved in 10% formalin. Samples with large amounts of debris were preserved with 10% formalin containing Rose Bengal dye to stain the larvae. These samples were returned to the laboratory for sorting.

Larvae which were not crushed or deformed during collection were measured to the nearest 0.1 mm (0.004 inch) using a microprojector.

A survey of striped bass spawning occurred in the lower half of the study area between May 1 and June 20, 1973. Sturgeon larvae collected during that survey were also enumerated and measured.

RESULTS

Catch

I collected 246 sturgeon larvae and nine sturgeon eggs. Eleven additional larvae were taken in the study area during the striped bass spawning survey. Sturgeon eggs are demersal and adhesive (Dees 1961; Nikolskii 1961), so the egg catch was expected to be small.

Larvae and eggs were collected only at the lower three stations. A total of 130 larvae and six eggs were captured at Colusa, 102 larvae and two eggs at rkm 180 (rm 112), and 14 larvae and one egg above the mouth of the Feather River (Figure 2). Mean catch per 30 min sample was 2.8 larvae at Colusa, 2.2 at rkm 180 (rm 112), and 0.2 at the Feather River.

Larvae were taken on the first day of sampling at Colusa and rkm 180 (rm 112). Catches peaked at Colusa on April 23 (49 larvae), at rkm 180 (rm 112) on March 19 (19 larvae), and at the Feather River

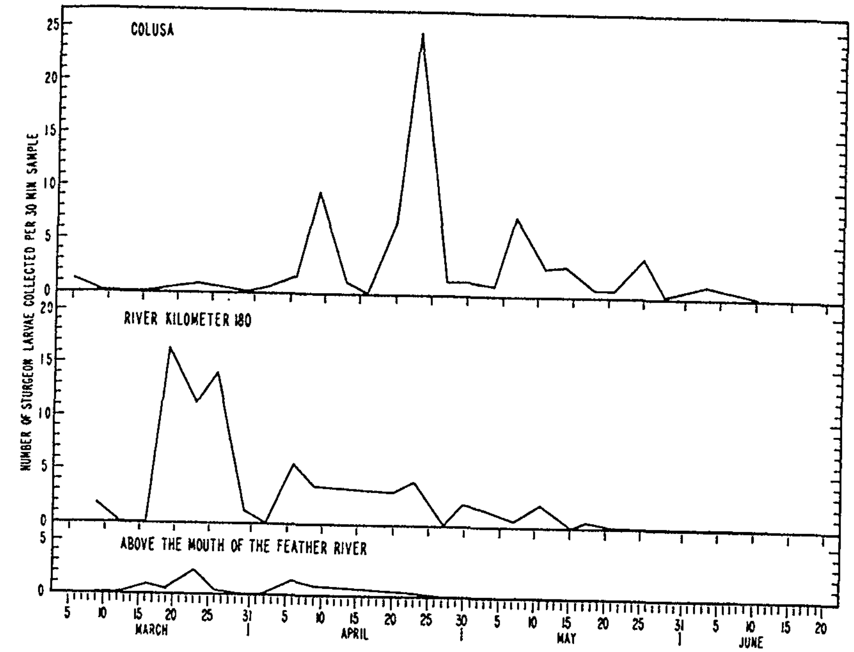

FIGURE 2. Temporal distribution of larval sturgeon caught during the sturgeon spawning survey in the Sacramento River in 1973.

Size

Mean length of the 206 sturgeon larvae measured was 11.6 mm (0.5 inch). One larvae was 5.2 mm (0.2 inch) long; the rest were between 7.2 and 19.5 mm (0.3–0.8 inch). Length frequency distributions were about the same for the three stations and differences in mean lengths between stations were not significant ($F = 0.69$, $P = 0.50$) (Figure 3). Length frequencies in different months were basically similar, but mean size increased slightly each month ($F = 3.75$, $P < 0.05$) (Figure 4), possibly reflecting a direct relationship between growth rate and water temperature.

Spawning Time, Temperature, and River Flow

Larval catches did not provide a direct measure of spawning time due to variable time lags between spawning and capture. To estimate spawning time, I assumed Sacramento River sturgeon developed at rates reported for European and Asiatic species (Cherfas 1956; Nikolskii 1961; Geibel 1966). These rates depend on temperature and are known for the incubation period and for the interval from hatching to active feeding. Only three of the 206 larvae I measured were shorter than 8 mm (0.3 inch) (Figure 4), so I assumed that was the approximate length at hatching. Larvae longer than 18 mm (0.7 inch) had well-developed mouthparts, had absorbed their yolk sacs, and had probably begun to feed. I used regressions of developmental rate on temperature (Figure 5) to estimate larval ages at 8 and 18mm (0.3 and 0.7 inches)

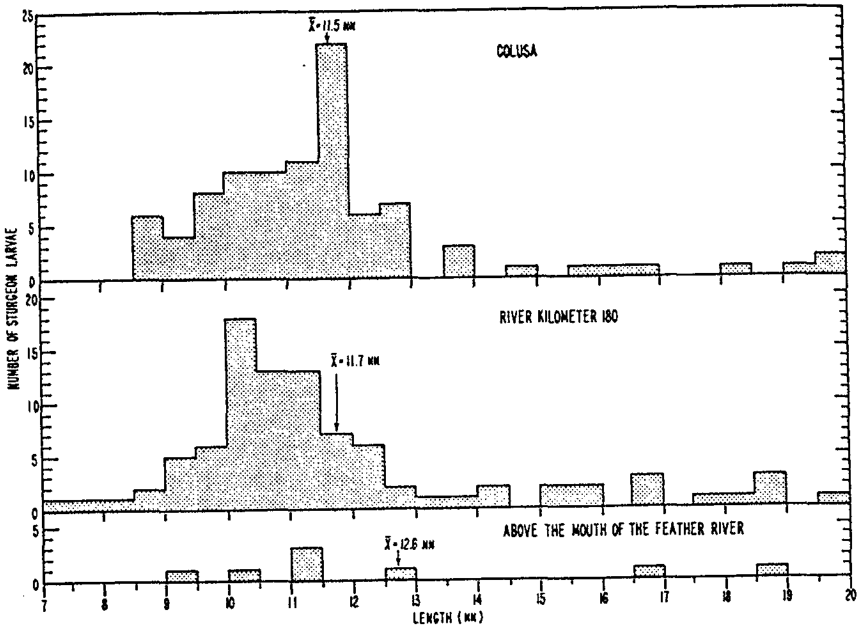

FIGURE 3. Length frequencies and mean lengths of sturgeon larvae collected during the *sturgeon spawning survey in the Sacramento River in 1973, arranged by sampling* locations.

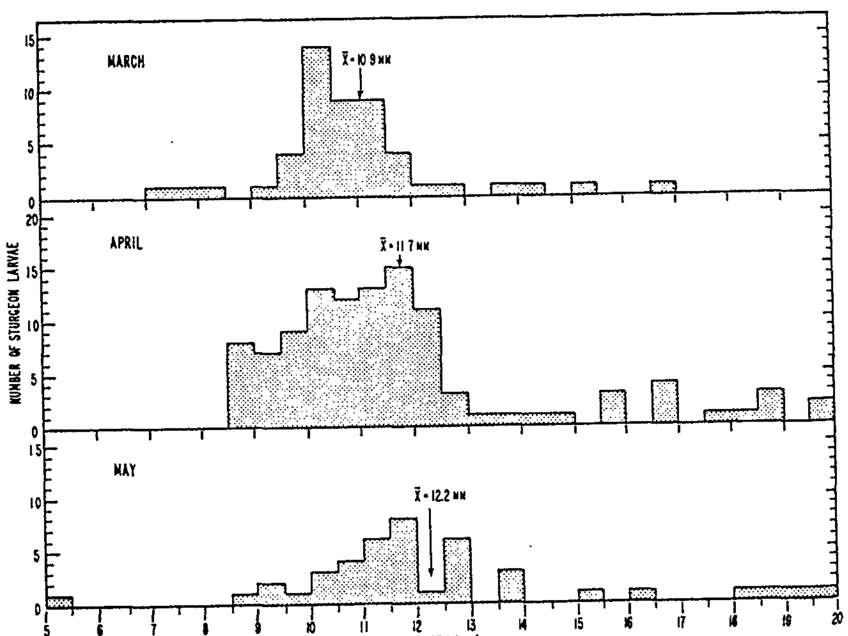

FIGURE 4. Monthly length frequencies and mean lengths of sturgeon larvae collected during the sturgeon and striped bass spawning surveys in the Sacramento River in

for temperatures observed during spawning and assumed linear growth between these ages (Figure 6). Since larval lengths at capture and approximate water temperature during development were known, the age of each larva (from spawning) could then be interpolated from Figure 6. These ages ranged from 5 to 25 days and averaged 12.4 days. They were subtracted from capture dates to calculate spawning dates.

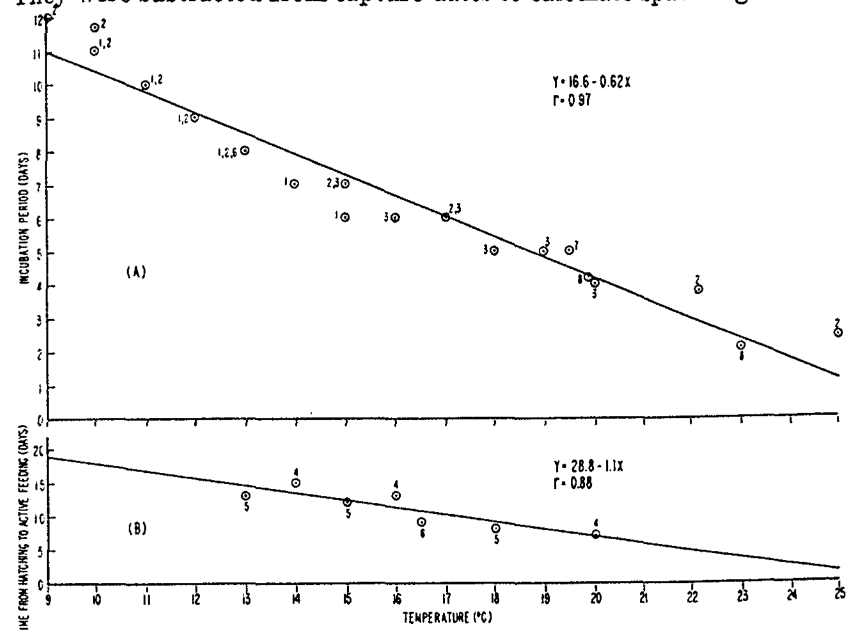

FIGURE 5. Relationship between water temperature and sturgeon larval development, derived *from the following sources and species:*
Geibel 1966
1. *Huso huso*
2. *Acipenser guldenstadti*
3. *A. stellatus*
Cherfas 1956
4. *A. guldenstadti*
5. *H. huso*
Nikolskii 1961
6. *H. huso*
7. *A. nudiventris*
8. *A. stellatus*
Line (A) was assumed to represent larvae 8 mm long and line (B) was assumed to represent larvae 18 mm long.

Estimated spawning occurred from mid-February to late-May, with 93% between March 3 and May 5 (Figure 7). During this two-month period, water temperature was 7.8–17.8 C (46–64 F). Maximum spawning (April 8–17) occurred at approximately 14.4 C (58 F). Maximum temperature during the spawning period was 22.2 C (72 F). There was no relationship between changing water temperature and spawning intensity.

River flows had no effect on sturgeon spawning intensity. While most spawning occurred during periods of decreasing flows, this is the dominant flow regime during the spring. There was no obvious flow threshold at which spawning was initiated.

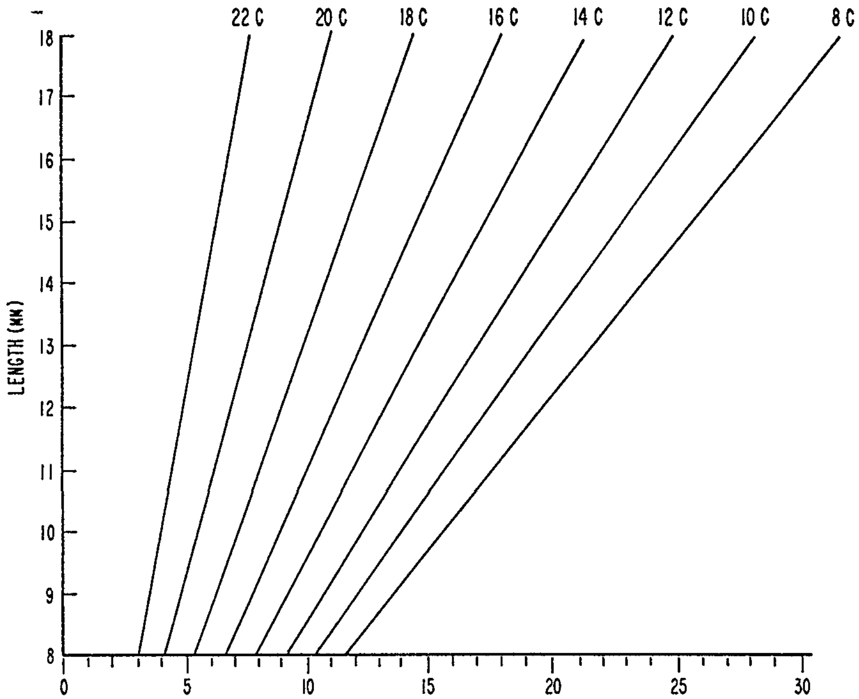

FIGURE 6. Relationship between age (since time of spawning) and length of sturgeon larvae at various water temperatures observed during sampling in the Sacramento River in 1973. These relationships were estimated from the regressions in Figure 5. If larval length and approximate developmental temperature are known, an estimate of larval age can be interpolated from this graph.

DISCUSSION

While small, the catch of 246 larvae provided good information on the location and timing of sturgeon spawning in the Sacramento River in spring 1973. The majority of spawning occurred from the vicinity of Knights Landing upstream to just above Colusa. Spawning was most intense during March and April, but probably began before mid-February since larvae were captured on the first day of sampling.

Information from my study generally agrees with that for other species of sturgeon in other river systems. Spawning dates for many species range from March to early July and spawning temperatures range from 9 to 24 C (48 to 75 F) Nikolskii 1961; Berg 1962; Geibel 1966; Magnin 1966). Some European sturgeon have two or more races migrating and spawning at different times (Gerbilskii 1951; Nikolskii 1961; Berg 1962). My study was not designed to determine if several spawning races exist in the Sacramento River system; however, the seasonal nature of sport catches (Miller 1972) suggests that the run of sturgeon moving upriver in late winter and spring is the major, if not the only, spawning group.

Sturgeon spawning sites are described as having gravelly or rocky bottoms where currents are moderate to fast (Dees 1961; Nikolskii 1961;

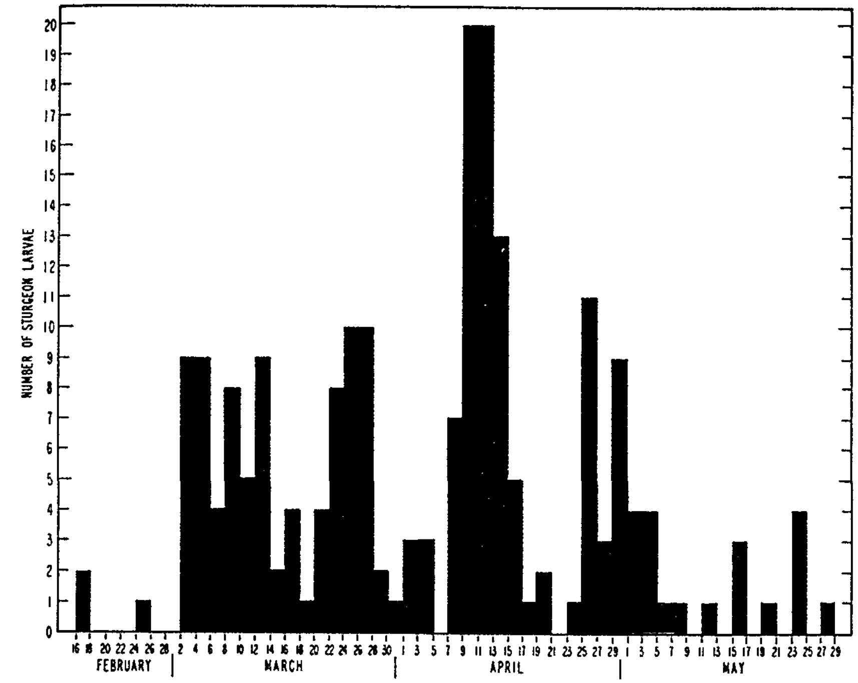

FIGURE 7. Sturgeon spawning periodicity in the Sacramento River in 1973, estimated from larval ages interpolated from Figure 6.

Berg 1962; Geibel 1966; Magnin 1966). Such conditions mainly occur upstream from Colusa in the Sacramento River. Below Colusa the river has a mud and sand bottom and moderate current. Since the spawning area apparently did not extend far above Colusa in 1973, my study disagrees with published descriptions.

Sturgeon probably spawn farther upstream in the Sacramento River than my study suggests. Between June 17 and July 10, 1974, 12 young sturgeon about 25–60 mm (1.0–2.4 inches) were collected at the intake of the Glenn-Colusa Canal near Hamilton City (rkm 330 [rm 205]) (Jerry Wise and Ronald Decoto, Calif. Fish and Game, pers. commun.). Therefore, either sturgeon spawned farther upstream in 1974 than in 1973, or the 1973 survey techniques were inefficient for catching larvae in that section of the river.

The sturgeon nursery is apparently formed by both the river near and below the spawning area and the Delta and bays downstream. Many larvae are flushed to the Delta and Suisun Bay in years with high runoff, but they are scarce there in years with low runoff (Stevens and Miller 1970). Hence, immigration age to these areas must vary with spring river flow. Spring 1974 flows were high, so the collection of juveniles near Hamilton City that summer and the scarcity of larvae in the Delta when flows are low suggests the river is an important nursery in all years. Although I did not catch sturgeon older than about 16 days, my stationary nets probably did not fish efficiently for them.

My larvae were not developed enough to be identified to species with existing knowledge. Identification requires counts of scutes along the lateral line, gill rakers, or dorsal fin rays (Schreiber 1960). Except for the small size (5.2 mm [0.2 inch]) and dark pigmentation of one sturgeon larva caught during the striped bass spawning survey, the larvae had no obvious features implying more than one species was caught. The predominance of white sturgeon in the system (Miller 1972) suggests that most of the larvae were white sturgeon. The small, dark specimen may have been a green sturgeon. A 60 mm (2.4 inch) juvenile taken at Hamilton City in 1974 was developed enough to be identified as that species, indicating green sturgeon do spawn in the river.

My study made no attempt to determine the existence or extent of sturgeon spawning in the San Joaquin River. Sturgeon larvae have been taken on the San Joaquin side of the Delta, but these could have come from the Sacramento River (Stevens and Miller 1970). Anglers often catch sturgeon in late winter and early spring in the San Joaquin River between Mossdale and the mouth of the Merced River. This migration is probably for the purpose of spawning, but no definitive evidence for this exists.

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THE ECOLOGY OF THE GAPER OR HORSE CLAM, *TRESUS CAPAX* (GOULD 1850) (BIVALVIA: MACTRIDAE), IN HUMBOLDT BAY, CALIFORNIA [1]

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The gaper clam populations of Humboldt Bay, California were studied from June 1969 through July 1973. Recruitments occurred primarily in the early spring of 1970 and 1971 and were not uniform in the clam beds. The beds were dominated by certain age classes but an age class did not necessarily dominate samples. Within samples no correlation existed between the density of established clams and the density of recruits. The spatial distribution generally was either random at low densities or aggregated at high densities. The standing crops for various beds were determined. Growth rates differed significantly between beds and between year classes within a bed. Von Bertalanffy growth equations were generated for various beds. Growth occurred primarily during the late spring and summer. Mortality of recruits was very high in 1970 and 1971 resulting in unsuccessful recruitment. Successful recruitment has not occurred since 1966. Adult mortality was very high in some beds. Predation by the moon snail, *Polinices lewisii*, Dungeness crab, *Cancer magister*, and a sea star, *Pisaster brevispinus*, was observed.

INTRODUCTION

The gaper or horse clam, *Tresus capax* (Gould), ranges from central California to Alaska (Morris 1966). The ecology of the gaper clam is poorly known even though the species is utilized as a sport clam. Its use as a commercial species has been encouraged in British Columbia (Bourne and Smith 1972b). The purpose of this study was to obtain ecological information which will aid in the management of the gaper clam in Humboldt Bay.

MATERIALS AND METHODS

The study areas in Humboldt Bay were below datum and consisted of single or sets of 2500 m² (26,910 ft²) plots (each symbolized by Q), transects, and areas where samples were non-randomly collected. Most of the study was conducted in the Primary Study Area located along the western margin of Southport Channel. This area was divided into 16 contiguous plots (Q_1–Q_{16}) (Figure 1). Additional plots were

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